THE MERCURIAL
CHRONOMETER
IMPROV'D:
OR, A
SUPPLEMENT
To a BOOK entituled,

An ESSAY, wherein a Method is humbly propos'd for Meaſuring equal TIME with the utmoſt Exactneſs; without the Neceſſity of being confin'd to Clocks, Watches, or any other HOROLOGICAL MOVEMENTS; in order to diſcover the LONGITUDE at SEA.

In which all Objections that are in the leaſt rational are remov'd, and the Method confirm'd.

By the Author of that ESSAY.

Eſt quòdam prodire tenus, ſi non datur ultrà. Hor.

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November 9. 1954

TO THE Impartial Readers.

THE Notion I had at firſt of Mercury, appeared to me ſo natural, and withal ſo rational, that I could not, even upon ſlight and imperfect Experiments, prevail upon my ſelf to delay penning it, long enough to make it entirely fit for the View of the Publick; which has occaſion'd ſome Faults and De-

fects in the ESSAY, *particularly nam'd in the Title-Page, which are not to be corrected otherwiſe than by the following Improvement: The chiefeſt whereof I take to be a Paſſage or two, where (for want of due Diſtinction) ſome Principles in the Law of Fluids ſeem to be contradicted: But neither this nor any other Overſight in it, can at all affect the Propoſal as to its main Deſign; which I hope will fully be made appear in the enſuing Pages.*

Since the publick Encouragement was given for finding out the Difference of Longitude, a great many Propoſals have been offer'd, and ſeveral Perſons have flatter'd themſelves with the Hopes of Succeſs, from Clocks, Watches, and other Movements.

But I believe, if this one Poſtulatum *were but duly conſider'd, which is, that mechanical Syſtems (ſuch as all* Automata *are) whether mov'd by Spring or Pendulum, conſiſting of different Parts or Members of a quite different Texture, muſt neceſſarily be af-*

affected by a Medium conſtituted of an infinite variety of Parts, and under a continual Mutation, in a very different Manner at different Times, or (which amounts to the ſame thing) they cannot be uniformly affected by the ambient Medium, the contrary to which was requir'd; and by conſequence no Rule can be found, according to the known Laws of Motion, to adjuſt the Differences, and make an Equation: This, I ſay, if it were maturely conſider'd, would without all doubt very much cool thoſe Mens Brains, whoſe Heads have run ſo much upon Wheels ever ſince the Commencement of a late Act of PARLIAMENT, *and put them upon thinking of new Methods for getting the Twenty thouſand Pounds. How far a certain merry* Longitudinarian'*s Watch, ſhut up* in Vacuo, *is likely to ſucceed, I muſt leave to better Judges than my ſelf to gueſs. However, he has aſſur'd the World he will try it, before he troubles the Commiſſioners with it; in which, I am ſure he is very much in the right.*

For my part, I muſt own I have not ſeen all the Books that have been publiſh'd on this Subject, neither ſhall I have the Curioſity nicely to inſpect every Propoſal about it, that either has been already, or ſhall be printed hereafter, having no Reaſon to doubt of the Succeſs of this Scheme, at leaſt as far as concerns the Improvement of Navigation, whenever it ſhall be duly try'd and proſecuted: Beſides I am not at all ſollicitous by what means the Diſcovery of Longitude, *ſo uſeful to all the trading Part of the World, is brought about: And if my Method ſhould fail (as I am verily perſwaded it cannot) I heartily wiſh (out of a true Zeal for the publick Good) that ſome Body's may ſucceed; yet I had rather that Honour were due to the* Engliſh *Nation than any other. I am,*

Gentlemen,

With all due Deference,

Calne, Feb. 15.
1714.

Your obedient
humble Servant,

J. Clarke.

THE

THE MERCURIAL CHRONOMETER *IMPROV'D*: OR, A SUPPLEMENT *to a Book, entituled*, &c.

EVERY Scheme that has any Dependence upon a mechanical Structure, muſt neceſſarily, at firſt, be but lame and imperfect: The Propoſal to which this is a Supplement, was writ under very great Diſadvantages,

tages, and could not, for want of due leiſure, be perfectly review'd and examin'd; for which reaſon I thought it abſolutely requiſite to add this further Improvement, by which (I am apt to flatter my ſelf) the Peruſers will find all reaſonable Objections remov'd, and muſt, I preſume, upon an impartial Scrutiny, look upon it likelier to ſucceed, than any Propoſal of this kind hitherto offer'd, that has not had a long Train of Experiments to confirm it. What I Deſign in this Supplement, in the firſt place, is to ſhew, How the Stream or Current of the Mercury may be kept continual and uninterrupted, and the Meaſure of Time computed by it, without loſing the leaſt Interval; which may be effected with great eaſe in the manner following:

Whereas in the Figure or Diagram (Eſſay, about Page 21) you find three Turn-cocks deſcrib'd; by this Contrivance all that Trouble may be avoided, and the Time meaſur'd much better without it. In the former, another leſs Inſtrument was requir'd to determine the Time elaps'd, whilſt you were returning the exhauſted Mercury; in order to which you muſt have ſtop'd one of the Turn-cocks, and immediately open'd the other, which could not well have been done without Loſs of Time.

But here you will need but one Inſtrument, which is to conſiſt of a Reſervoir, to contain a due Weight of Mercury, one Turn-cock, and two Receivers of a quite different Figure from any I have yet propos'd: The firſt of theſe, that is to ſay, the Reſervoir, may be either a perfect Cylinder of about five or ſix Inches Diameter, or about two thirds of it ſo, and from thence terminate in a Cone, or in a leſſer Cylinder. The ſecond Part of this Inſtrument muſt be a Turn-cock made with a double Out-let, that is, it muſt be furniſh'd with two deſcending Tubes, in each of which a Hole muſt be drill'd as ſmall as poſſible at the Top, to let go a perpendicular Stream into either Receiver, as the Caſe ſhall require; which Tubes are to be open'd and ſhut alternately, by one Turn of the Hand; ſo that by this Means you may ſtop one Stream while the other is running, or both at once, if it were at any time requir'd; and thus you may (whenever you pleaſe) preſerve a continual Current without ſenſible loſs of Time; the manner whereof, together with the Structure of theſe two Parts of the Inſtrument, is particularly deſcrib'd in the Figure hereunto annex'd, and may be perfectly underſtood by it, without further explanation; to which therefore I refer you.

But it will not be improper in this place, to give you a ſhort Deſcription of the new Form of the Receiver, by which it may be the better conceiv'd wherein it differs from that which was firſt recommended.

This Receiver will have a great Advantage above either of thoſe which were at firſt propos'd, in the Menſuration of Time by Inſpection, which is by far the moſt expeditious way of Computation, and therefore the moſt uſeful at Sea; and will, by the following Contrivance, be found to be as exact in Practice, as any whatſoever.

Let a pretty long cylindrical Glaſs be made with diagonal Tubes, as ſmall as thoſe of a Barometer, communicating at top and at bottom with the Hollow of the Cylinder, making equal Angles with its Axis; and let theſe Tubes be divided into Hours and parts of an Hour, in proportion to the Size of the Receiver you deſign for your uſe, by employing a Royal Pendulum for that purpoſe, which may be very well underſtood without particular Directions; and by the help of theſe parallel Diviſions you will be able to determine, to an Hair's Breadth, when your Receiver is in a true perpendicular Poſition, and by conſequence the true Hour and parts of an Hour, by the Graduation on the diagonal Tubes; neither is it any matter in this caſe, whether equal Quantities fill equal Spaces in equal Times, ſince any determinate Altitude or Space which the Fluid occupies, is equal to its ſelf, and the Times will be known by the Spaces fill'd, whether they are greater or ſmaller, ſo long as the Current is puſh'd on by an uniform Preſſure of the parts of the Fluid: That is, ſuch a determinate Space will always be fill'd in ſuch a determinate Time, where the Columns of the Fluid from whence they are fill'd, were at firſt of the ſame Height and Dimenſions. Thus much for determining the Time by Inſpection.

In the next place we are to conſider, How near it may be done hydroſtatically, or by weighing the Quantities exhauſted under the ſeveral Altitudes of the Mercury in the Reſervoir, to ſatisfy ſuch whoſe Curioſity may require it: And here we muſt obſerve, that tho' the Method propos'd in the Eſſay, mention'd in the Title-Page, (where three Veſſels are ſo apply'd to each other, that the ſecond is to empty the firſt, and the third the ſecond) would, with a ſmall variation of the Figures, and proportions of the Veſſels to each other, be brought ſo near to exactneſs, that the Difference of the Weight exhauſted by the laſt, in proportion to the Times, would vaniſh to almoſt an immenſurable Smallneſs, even in a great Quantity of the Fluid; yet becauſe, according to a known Principle in the Law of Fluids, the Velocity of a Fluid deſcending after this Manner, will be always in a *Ratio* compounded of the Height of the Fluid above the Hole, added to the Height of the Hole above the Place on which the Stream falls; the former way, how near ſoever it may anſwer in Practice, will fall ſhort of Demonſtramonſtration; and therefore I ſhall endeavour to ſhow after what manner the Mercury may be diſpos'd, that equal Quantities may run out in equal Times; in order to which, Let an exact Cylinder of thick Glaſs, or fine Wood, repreſented by the Letter *A*, be made jetting out in the Bottom, in a ſmall cylindrical Nook, for the Mercury to run all out in a perpendicular Stream thro' the ſmall Out-let *f*, and let it be ſome way or other faſten'd to the fix'd Frame, ſo that the inner Frame *a a a a*, may have liberty to ſlide up and down with great eaſe in two Grooves made in the former. From the Top of the Frame *a a a a* muſt come a Stem of Wood, which muſt be faſten'd into a round Plate of Box, or ſome ſuch fine Wood, ſomewhat leſs in Diameter than the Cylinder, which Plate is repreſented by *c c*; then let a Plate of Glaſs, much leſs in Diameter than that of Wood, ſomewhat convex on that ſide which is to receive the Stream, be faſten'd at the Bottom of the ſliding Frame *a a a a*, by the means of croſs Bars, or otherwiſe, as may be eaſily conceiv'd; which muſt be as far from the Plate *c*, as the Plate *c* is from the

the other end of the Frame: Laſtly, muſt two cubical Veſſels, or ſuch as are of a rectilineal Figure, exactly fitted to each other (as by the Figure may be ſeen) be put underneath to receive the Mercury, and be ſupported by a Board, made to ſlide backward and forward on two Brackets, near the Bottom of the outward Frame, to let the Stream fall into the Mouth of the furthermoſt Receiver, whilſt that which is next you is taken away, in order to be weigh'd and empty'd into the Cylinder without the leaſt Interruption or Loſs of Time: After this the Frame *a a a a* being drawn up as high as it will go, the Cylinder *A* muſt be fill'd, or almoſt fill'd with Mercury: Then being let down that the Plate *c* may reſt on the Surface of the Mercury, which will buoy up the whole Frame *a a a a*, for which reaſon it ought to be made very light, let the Out-let *f* be open'd by means of a Turn-cock, and the Mercury will always fall on the Plate of Glaſs *d*, and ſo run off into the Veſſel underneath; and the Plate *d* will continually ſink, as the Mercury ſinks in the Cylinder, becauſe it is a part of the Frame which the Mercury buoys up:

Now according to the Principle before laid down, which is, that the Velocity of the Stream or Current is proportional to the Height of the Fluid above the Hole, added to the Height of the Hole above the Place on which the Stream falls; I ſay, equal Quantities of Mercury will run out in equal Times: For if the Height of the Mercury above the Hole be added to the Height of the Hole above the Place on which the Stream falls, the Sum or Aggregate will be always the ſame; whence 'tis evident, the Velocity of the Current will be the ſame alſo, and therefore equal Quantities of Mercury will always run out in equal Times: *Q. E, D.* See the Figure at the End of the Book.

Among many trifling Objections againſt the uſe of Mercury in meaſuring of Time I have heard it has been condemn'd upon the account of the Diſſimilarity of its Parts, and that there are different Sorts of Quickſilver differing in Gravity, and alſo that it may be heavier at one Time than another; all which look more like idle and empty Speculations than fair and ſolid Objections, grounded upon any cer-

tain

tain Experiments. If they mean by Diſſimilarity of Parts, any thing lodg'd in its Pores that is not mercurial; there are ſeveral ways of refining it, amongſt which the moſt common and uſual are, Percolation through Leather, and Diſtillation by Fire, which every common Chymiſt can perform, and by that means free it from any thing of a different Texture from itſelf; and when any Perſon lights on any two parcels of pure and ſimple Mercury of a different ſpecifick Gravity, the Sight of it will very much oblige me: But if there were any ſuch thing, I can't ſee how it can affect this Propoſal, ſince by the Help of the Barometer and Thermometer, all Inequalities that can happen to it from the Change of the Air, may by frequent Trials be determined and adjuſted, as is mention'd more at large in the Treatiſe to which this is a Supplement. Beſides, it does not appear from any exact Diſcoveries, that a different Conſtitution of the Air can affect it at all in this Caſe, becauſe according to a known Principle, The Velocity of an effluent Fluid is the ſame, in any thin Medium where its perpendicular Altitude is the ſame. Suppoſe then, the Air

Air to be more elaſtick at one time than another (to which perhaps the Aſcent and Deſcent of the Mercury in the Barometer may be chiefly owing) the Body deſcending thro' the Medium will be affected from it on all ſides, by an uniform Reſiſtance and Preſſure; and therefore muſt neceſſarily deſcend according to the conſtant Law and Tenor of its own comparative Gravity, and ſo not be liable to an encreaſe or decreaſe of Velocity upon that account.

It would be almoſt endleſs to take notice of all the Scruples, that may be raiſed againſt this, or almoſt any other Project, before it is fully try'd by ſuch as have leiſure enough, and perhaps whoſe Intereſt it is, to object: But indeed, ſince this Eſſay was publiſh'd, I have often conſidered, whether a much leſs Weight of Mercury than ninety Pounds would not be ſufficient to meaſure a Period of three Hours, which was firſt propoſed; and to this End I attempted to drain it through a much leſs Orifice than before: But living remote from *London*, or any other Place where they are expert in making convenient Glaſſes, I was obliged to make my Experiment in a much homelier manner, than I ſhould have otherwiſe done: For inſtead of thoſe Helps, I was forced to content my ſelf with a common long Phial, which I cut off at Bottom, and paſſing the end of a Quill through a Cork, that juſt fitted the Mouth of the Glaſs, letting the open end of the Quill enter into the Hollow of it, and the other, which was cloſe, remain without the Cork about a quarter of an Inch in length, I cloſed it ſo firmly with ſealing Wax, that not the leaſt Particle of any Fluid could eſcape through. After which I burnt a fine Hole in the ſide of it, pretty near the Top, with the Point of a ſmall Needle, and brought the Mercury to run through it: And by this laſt Experiment I found that about three quarters of a Pound would meaſure ten Minutes of Time, which is about the Rate of thirteen Pounds to three Hours: Nor do I think ſuch a Quantity as would be enough to meaſure double that Time, would be at all unmanageable at Sea. Through how ſmall a Vent 'tis poſſible to drain Mercury I cannot determine, but I am perſuaded it will paſs through an exceeding ſmall Hole, if it were finely drill'd in Glaſs, or ſome hard Body capable of a Poliſh.

Upon a ſtrict Survey of the whole, I can ſee no colour of Reaſon why this Scheme ſhould not ſucceed, even in the manner it is already propoſed, abating only for the Improvement of Inſtruments; yet if there ſhould ſtill remain ſome trifling Diſputes about the Changes of the Air, that nothing may be wanting to compleat this Method I ſhall ſhew you how all thoſe Scruples may be remov'd beyond Objection; and that is, by putting the Inſtrument or Chronometer into a quite different Form, and exhauſting the Air that the Mercury may run *in Vacuo*. For by the *Boylean* Experiments it appears, That all Bodies in an exhauſted Receiver deſcend equally faſt towards the Centre of Gravity; and the Changes of the Atmoſphere can have no Effect here, nor can the Mercury thus confin'd, be affected by a mixture of parts of a different ſpecifick Gravity, or by different Degrees of Heat and Cold, ſince we cannot find, when it is expoſed to a Heat conſiderably greater than any under the Æquator, that the leaſt Particle aſcends.

Now to put this Inſtrument into ſuch a Form, as may anſwer every end that can be expected from the moſt perfect and compleat Chronometer:

Let two hollow Cylinders of Glaſs, of an equal Length and Diameter, be prepar'd according to the Figure, and be joyn'd or united to each other at their convex Extremities, as one entire piece of Glaſs; alſo, let a ſmall and long Stem, or Tube of the ſame Glaſs, proceed from each end, or from one only, as the Artificer ſhall judge moſt convenient for his purpoſe, through which to paſs a Drill in order to work a Hole, as ſmall as poſſible, through the Point of Contact, to communicate with the two ſimilar Cavities; then if the Glaſs be made with two Stems, let one of them be Hermetically ſeal'd, and cut off as cloſe to the Flat of the Glaſs as may be; which done, convey into that Glaſs, whoſe Tube is cut off, through the other Tube, as much ſtrain'd or purify'd Mercury free from all Moiſture, as is juſt enough to fill its Cavity up to the Hole of Communication. After this, ſome way muſt be contriv'd to fix a ſmall Air-Pump to the Top of the Tube, and when the Air is exhauſted, it muſt be

kept

kept by the ſame Means excluded, while two or three Hands are employ'd in melting, twiſting, and cutting off the Bottom of the Stem or Tube, as near as it can be done to the Flat of the Glaſs, by the means of large Candles or Lamps, a circular iron Frame like a Grate, with Charcoals placed round and Blow-pipes; or any other way, as may be found more agreeable to Practice, about which I cannot pretend to give particular Directions: But I make no doubt, but there may be ſeveral Perſons dexterous enough to ſeal a Glaſs thus Hermetically, eſpecially ſince the making and ordering of Glaſs is arriv'd in this Age to an amazing Degree of Perfection.

Having briefly ſhown in what manner the Mercury may be diſpoſed to meaſure equal Time, it may perhaps be expected, I ſhould mention ſomewhat concerning the Uſe of the Inſtrument; but this is ſo obvious that it needs no particular Explanation; becauſe 'tis little more than what is required in turning a common Hour-Glaſs when it is run out. For in the Frame there is a Pin whereby to draw back a Spring, which lets it free from the Bolt or Piece of Wood that holds it faſt; by which means the other End may be turn'd up, and the Bolt receiv'd into the like Cleft or Notch, in which it will be kept firm by the Strength of the Spring; and thus it may be in a Moment of Time turn'd up and down. And if at any Time it ſhould be thought fit to employ an Inſtrument of this kind, to meaſure a much longer Space of Time, it may be made to be turned up with as much eaſe as this and as ſpeedily.

POSTSCRIPT.

THE Deſcription of the Frames repreſented by *Fig.* 1. ſeeming a little too obſcure to be perfectly underſtood, I thought it adviſeable to add this further Explanation. In the firſt Place you are to underſtand the outward Frame ought to conſiſt of twelve Sides, and the ſliding Frame only of four. In the next place the Cylinder muſt be faſten'd into a thick Frame or Caſe of Wood, to be faſten'd into the outward Frame, by means of four Bars on each Side, coming from the Top and Bottom of the Caſe of the Cylinder, and entring into the Sides of the outward hollow Frame, whoſe Sides muſt be made very ſtrong. In the Caſe of the Cylinder, two Grooves muſt be made for the ſliding Frame to move very freely in. Alſo to prevent waſting the Mercury, a concave Glaſs open at both Ends, the upper Mouth reſembling that of a Phial, and of a ſpheroidical Figure, ſomewhat like a Glaſs Funnel, muſt be faſten'd ſo to the ſliding

ſliding Frame, that it may cover the ſmall Plate of Glaſs in the manner of a Dome; yet ſo as not to touch the ſame: The Brackets, mention'd in the firſt Deſcription of the Frame, whereon the Board is to ſlide, muſt be four in number, and in the inſide of the outward fix'd Frame.

The diagonal Tubes deſcribed in *Fig*. 2. ought to lie in Planes interſecting each other; or there may be three Tubes: For if there be but two lying in the ſame Plane, you will not be able to know exactly when the Inſtrument hangs perpendicular to the Horizon.

Laſtly, Theſe Diagonal Tubes ought to be let into Wood, to ſecure them from Injury, and to each Diagonal Tube thus plac'd you may have Braſs Index's to move up and down, and point to the ſeveral Diviſions, as is common in Barometers.

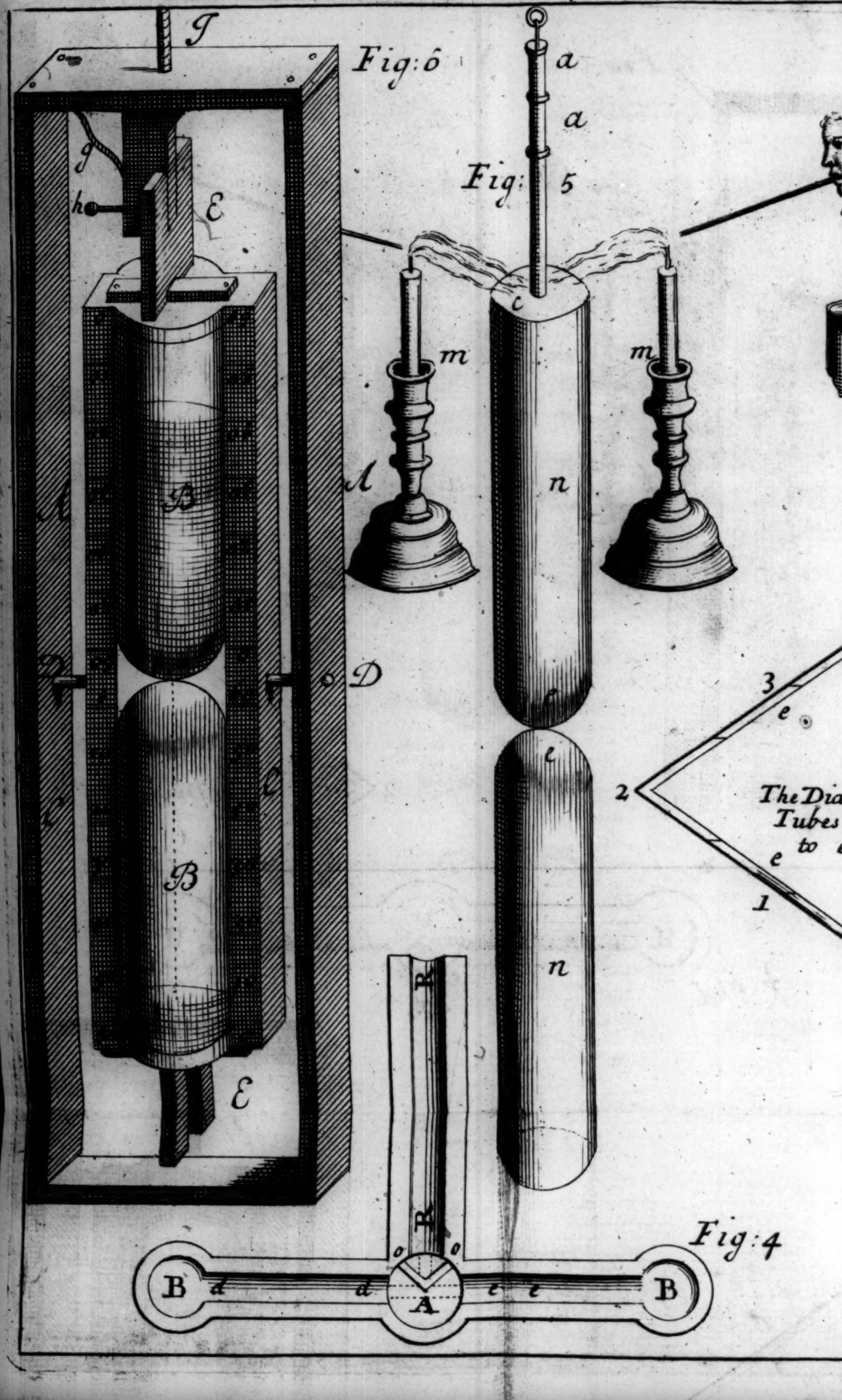
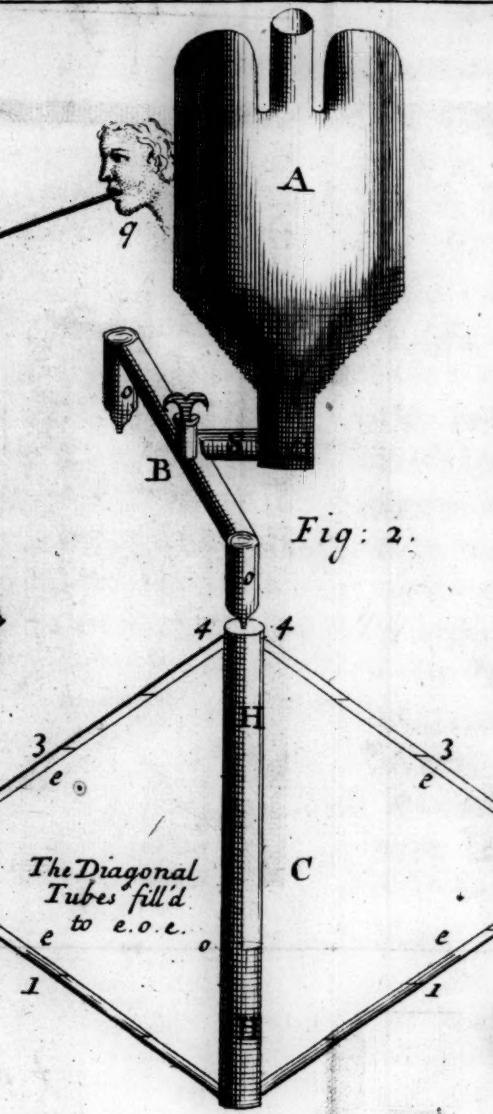


Fig:6

Fig: 5

Fig:4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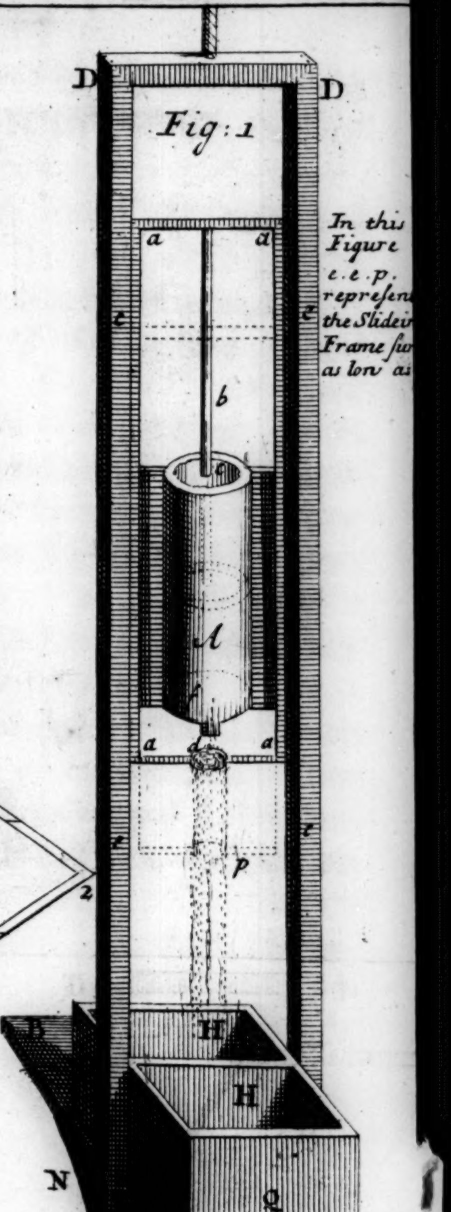
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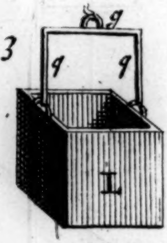

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The Explanation of the Figures.

F I G. I.

D*DDD.* The outward Frame.

aaaa. The ſliding Frame.

eeee. The Grooves for the Frame to ſlide in.

A. The Cylinder to hold the Mercury.

f. The Outlet.

c. A Thin Plate of fine Wood faſten'd into a Stem that comes from the Top of the ſliding Frame.

(*aa*) *b.* The Stem it ſelf. *d.* A ſmall Plate of Glaſs, Agate, or the like, for the Stream out of the Cylinder to fall upon.

QQQ. The Sides of the two rectangular Receivers fitting cloſe to each other.

HH. Their Mouths to receive the Stream alternately as the caſe ſhall require.

B B. The Board or Plate of Wood which ſupports the Receivers, made to ſlide backward and forward.

N. The Bracket upon which it ſlides.

FIG. II.

A. The Reſervoir conſiſting moſtly of a cylindrical Figure.

B. The Turn-cock.

oo. The two deſcending Tubes.

C. The Receiver.

eeee. The diagonal Tubes to meaſure the Height of the aſcending Mercury.

1 2 3 4. The ſeveral Heights of the Mercury, to be divided into as ſmall Parts of Time as you can.

HH. The perpendicular Cylinder or main Body of the Receiver, with which the diagonal Tubes communicate, making equal Angles with its Axis.

FIG. III.

L. The rectangular Receiver, with a Handle (*qq*) to raiſe up or let down.

g. A Hook in it by which it may be hang'd on a Balance.

FIG. IV.

RRABB. The geometrical Plane of the Turn-cock, whoſe Perſpective is repreſented in *Fig.* 2. by *oBoS.* *RR.*

R R. The ſtrait Canal that receives the Mercury from the Reſervoir.

e e, d d. Another ſtrait Canal croſſing the former at right Angles, and communicating with it by means of the rectangular Canal *o A o,* which by being turn'd round till *o* is brought over-right *ee,* the other end mark'd with *o* alſo, will be over-right the main Canal *R R,* and derive the Current into *e e,* whilſt *d d* is ſtop'd; and on the contrary. *A* repreſents the *Section* of the cylindrical Stopple, in which the right-angl'd Hole or Conduit *o A o* is bor'd. *B B.* The Bores of the deſcending Tubes, *o o,* repreſented in *Fig.* 2.

F I G. V.

By *a a,* the Air-Pump is repreſented, as cemented to the Stem of the cylindrical Glaſs *a c.* *e e.* The convex Ends of the Cylinders meeting in a Point.

By the Letters *q mm, nn, ee, a, ac,* the whole Operation of ſealing the Glaſſes is repreſented.

F I G. VI.

A A. The outer Frame in which the Horometer hangs.

B B. The two Glaſſes of the Horometer.

C C. Two Bars of Wood whereon is mark'd the Diviſion of Time in Minutes.

D D. The Axis on which the Horometer turns.

E E. Two Pieces of Wood with Notches in them for turning the Horometer.

F. A Piece of Wood which ſlips into the Notch of either of the fore-mention'd Pieces, for keeping the Horometer upright.

g. A Spring for keeping the Piece of Wood from the Notch.

h. A Pin for pulling back the Piece of Wood or Bolt in turning the Horometer.

I. A Rope whereby the Whole is ſuſpended.

F I N I S.